Facing the Reality of Operating with Minimal TDRSS Support

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Introduction to the Earth Observing System

Earth Observing System (EOS) comprises a major portion of NASA's Earth System Science Enterprise Program

Instruments on series of EOS spacecraft will provide a comprehensive study of earth systems (land, atmosphere, water)

Studies will provide an environmental data base on global climate change

Program scheduled to operate over a 15-18 year period

EOS Data and Information System (EOSDIS) provides spacecraft

- Command and control
- Data processing
- Product generation
- Data archival and distribution services

Changes to EOS Concept

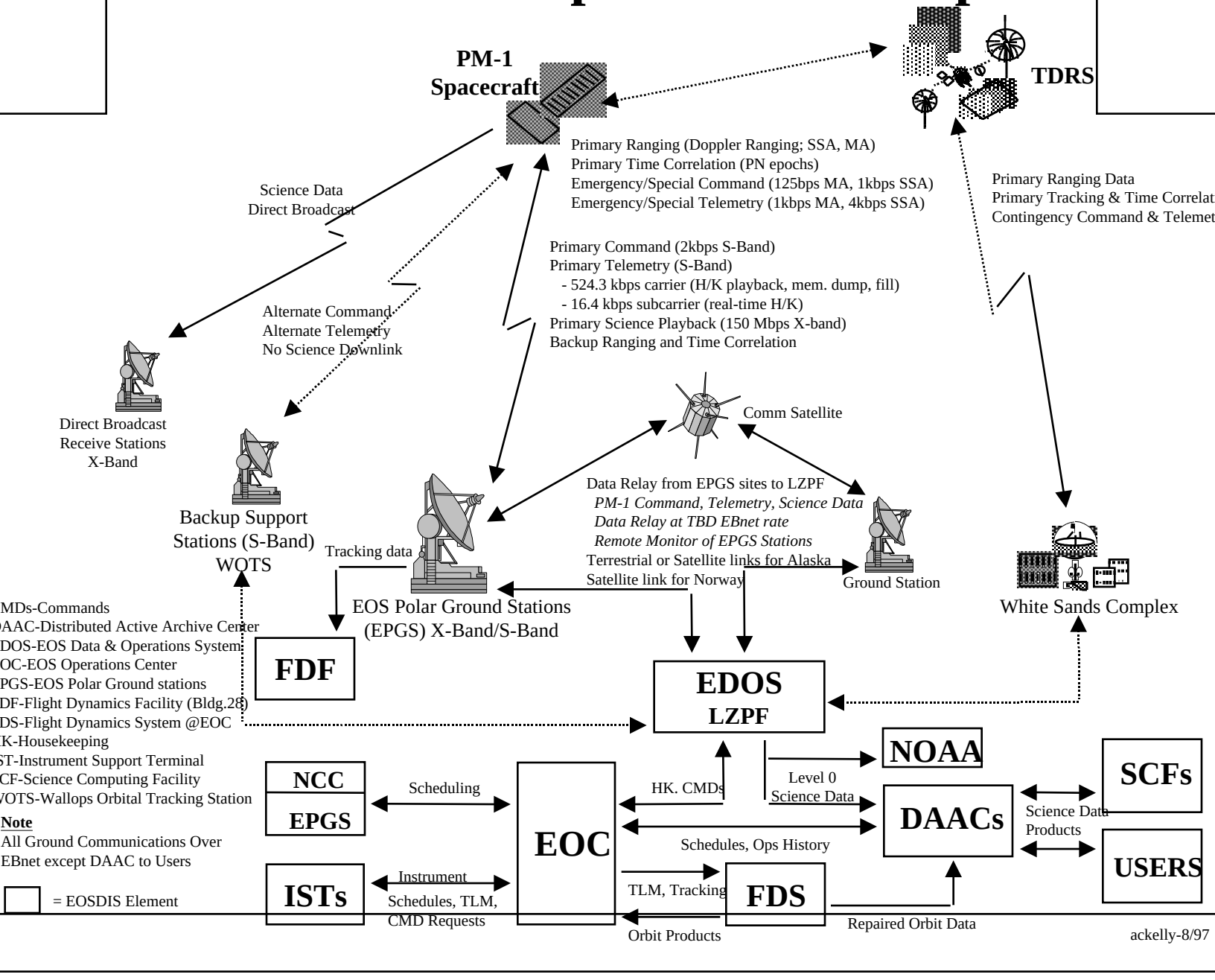
1990: Primary data acquisition interface with EOS spacecraft usin TDRSS.

1994: Study to utilize X-band for downlink resulting in reduced costs (“faster, better, cheaper”).

1996:

- Directed to implement the ground station-based support concept by using polar grounds stations as prime data acquisition interface with EOS spacecraft.
- Existing NASA ground stations could not support required data at 150 Mbps Development the EOS Polar Ground Stations (EPGS) started at Poker Flat Research Range, Fairbanks, Alaska (AGS) and Longyearbyen, Spitsbergen, Svalbard, Norway (SGS).

PM-I Mission Operations Concept



EOS Polar Ground Stations Implementation

Phase I

- Integration of mission specific equipment in Alaska and Norway
- Back-up support for AM-1, Landsat-7, Earth Orbiter-1, and QuikScat
- Operational by July 1998
  - T-1 line for S-band data transport to GSFC
  - X-band science data captured on tape and shipped to user facility (T-3 high rate telecomm links for X-band science data implemented if AM-1 high rate link via TDRSS fails)
  - Development of Phase 2 --mission modeling, loading analyses, architecture development, and RF Interface Control Document generation

Phase 2

- Installation of additional antennas and ground station equipment to provide adequate X-band telemetry downlink strings, S-band telemetry downlink strings, and S-band command uplink strings
- Operational by June 2000
  - T-1 line for S-band data transport to GSFC
  - T-3 high rate telecomm links for X-band EOS science data transport to GSFC

Mission Profiles

EPGS Loading Analysis Data

	Orbital Data Volume	Onboard Storage Capacity	Downlink Rates (bps)	Real-Time Monitoring Requirement	Data Delivery Requirements (EDOS Latency)	Command Requirements (Freq., Duration)	Orbit Design Requirements	Tra Rc
	110 Gbits	160 Gbits	150M (X-PB) 512K (S-PB) 16K (S-RT)	1 pass per orbit (minimum)	Science: 24 hr. Science: NRT (NOAA) H/K PB: <30 min. H/K RT: real-time	1 pass per day for loads RT each pass for PB	705 km circular 98.2 inclination 10:20 Descending Node	150m TDR (TBD
7	Imaging: 878 Gbits/day[8] 45MB/day H/K	378 Gbits	150M (X-PB/RT) 256K (S-PB) 1 or 4K (S-RT)	4 AGS pass/day 2 SGS pass/day	Science[2]: 48 hr. (tapes) H/K PB: real-time H/K RT: real-time	AGS DN passes for loads uplinks (2/day) RT each pass for PB	705 km circular 98.2 inclination 10:00 Descending Node	375m N SN, L
T	5.178 Gbits/Day	8 Gbits	2M (S-sci PB) 256K (S-HK PB) 16K (S-HK RT)	1 pass per orbit	Science: NRT (NOAA) H/K PB: < 30 min H/K RT: real-time	2 CMD loads per day (10 min. each)	803 km circular 98.6 inclination 06:00 Ascending Node	1000m WOT p
	80 Gbits/Day	40 Gbits	105M (X-PB) 1M (S-PB/RT) 2K & 32K (S-LEO) 4M (S-PB cont.)	2 passes/day	*Science Tapes: 48 hr.* H/K PB: 1 hr. (FTP) H/K RT: real-time	*1 pass per day for loads* *RT each pass for PB*	705 km circular 98.2 inclination 10:01 Descending Node	EPG doppl GPS (TBD
	47 Gbits	136 Gbits	150M (X-PB) 524K (S-PB) 16K (S-RT)	1 pass per orbit (minimum)	Science: NRT (NOAA) H/K PB: <30 min. H/K RT: real-time	1 pass per day for loads RT each pass for PB	705 km circular 98.2 inclination 13:30 Ascending Node	500m TDR (TBD
	1.6 Gbits	24 Gbits	16K(S-RT) 256K(S-PB) 40M (X-PB)	4-6 passes/ day	Science: 24 - 48 hrs H/K PB: <30 min. H/K RT: real-time	4 RT pass/day for PB 1 or 2 loads per day	600 km circular 94.0 inclination No nodal requirement	5cm GPS/S EPGS r
	33 Gbits	88 Gbits	150M (X-PB) 524K (S-PB) 16K (S-RT)	1 pass per orbit (minimum)	Science: NRT (NOAA) H/K PB: <30 min. H/K RT: real-time	1 pass per day for loads RT each pass for PB	705 km circular 98.2 inclination 13:45 Ascending Node	500m TDR (TBI

spacecraft communications antennas are assumed to support horizon-to-horizon line-of-site coverage with ground stations (5 degree minimum elevation).

nformation for EO-1 and beyond is subject to change.

numbers in parenthesis are the minimum number & duration of tracking passes/day needed to support mission accuracy requirements, assuming all tracking data was provided by EPGS.

GS tracking data from planned communications passes (6/day total) will constitute approximately half of the collected tracking data, and will be augmented by LGS and SN data.

dsat-7 pass times: AGS AN between 04:00 and 09:00 GMT, AGS DN between 18:00 and 24:00 GMT, SGS passes between 10:00 and 16:00 GMT. All passes require S-BD and X-BD suppor

GS provides supplementary pass support for L-7; prime support is provided by the Landsat Ground Station (LGS). Data volume downlinked to EPGS is limited to 6 passes X 150Mbps (~540 G

EPGS loading year is 2004; AM-1, Landsat, PM-1, CHEM-1, ICESAT, and AM-2 all supported simultaneously (6 spacecraft).

~~ed addition to Mission Set: TOMS - EP~~

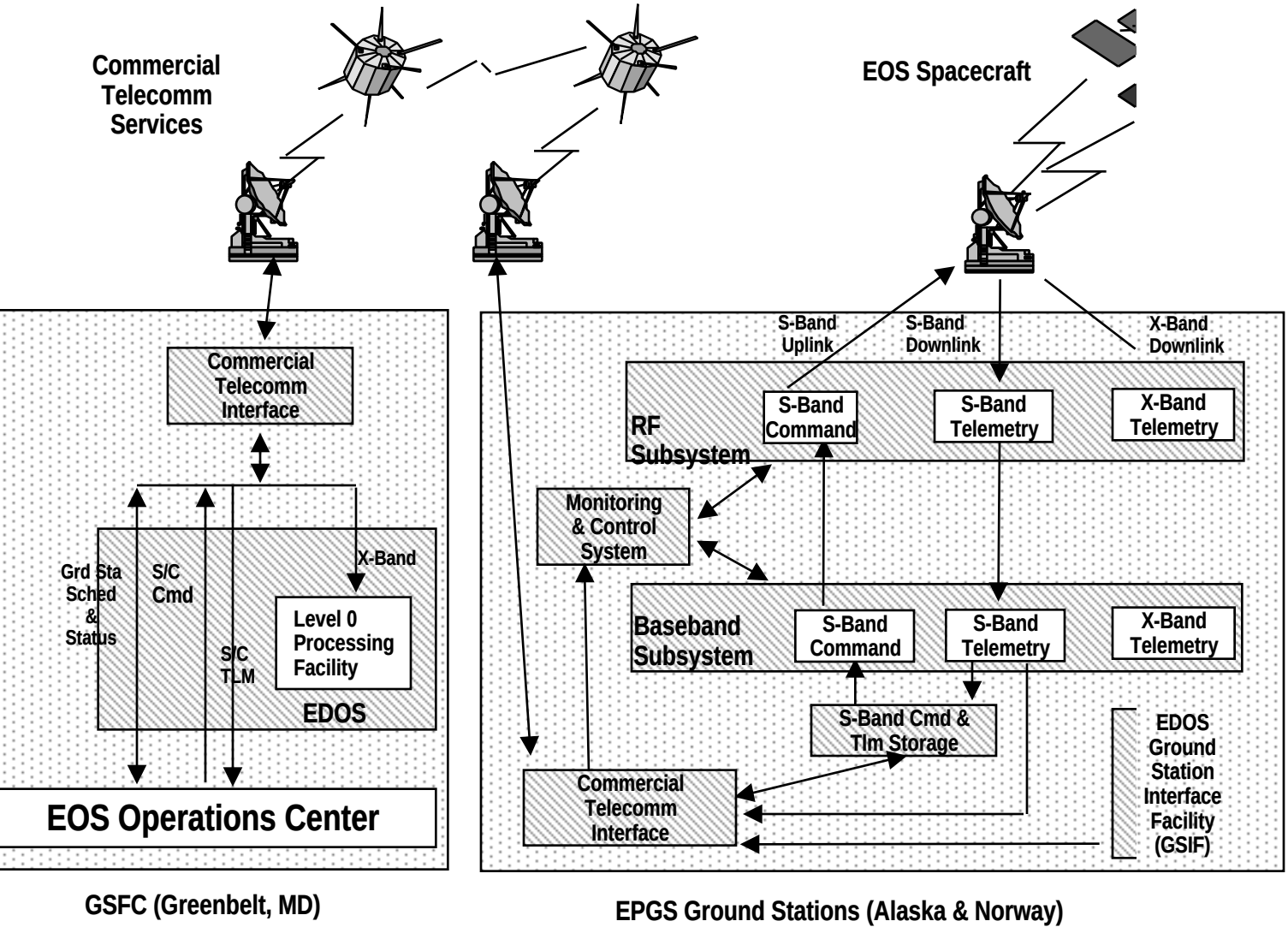
**** Refer to each mission's EPGS RF ICD for details of the format of each***

C. Kelly, 4/2/98

EOS AM-1 and PM-1 Coverage

Orbit	# Minutes (at 5 degree elevation)		
	Alaska	Norway	Total
1	0	11.9	11.9
2	0	12.2	12.2
3	8.8	12.9	21.7
4	12.8	13.5	26.3
5	13.4	13.3	26.7
6	11.7	12.0	23.7
7	8.5	10.1	18.6
8	6.4	8.7	15.1
9	8.3	9.2	17.5
10	11.5	11.2	22.6
11	13.4	12.8	26.2
12	12.9	13.5	26.5
13	9.3	13.3	22.5
14	0	12.5	12.5
Total	116.9	167.1	**284.0**
Average	8.3	11.9	**20.3**

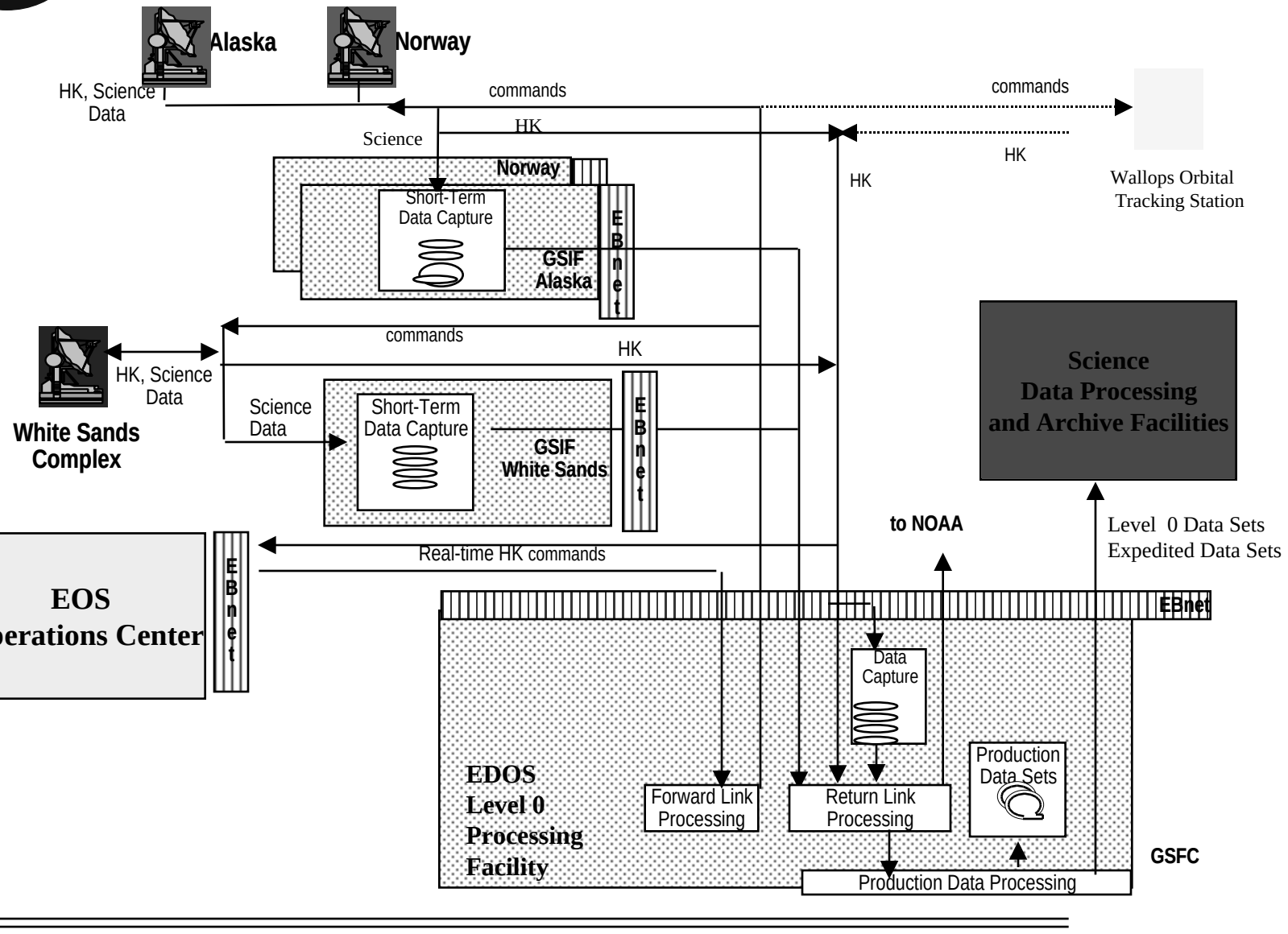
EPGS System Overview



GSFC (Greenbelt, MD)

EPGS Ground Stations (Alaska & Norway)

EDOS Configuration



Minimum TDRSS Support Configuration

EPGS for high rate science data downlink via X-Band

EPGS for primary S-Band command and control function

TDRSS only in a back-up or emergency mode for S-Band command and control

TDRSS for primary tracking and time correlation

TDRSS only during launch and early orbit

EOS Ground System Function Allocation

Ground System Function	Original (at White Sands)	Adap at White Sands	at I
Spacecraft uplink/downlink interface	X	X	
EDOS High Rate Interface	X	X	
EDOS Low Rate Interface	X		
EDOS raw science data capture	X	X	
EDOS raw HK data capture	X		
Realtime processing (HK)	X		
Playback Processing (HK)	X		
Level Zero Processing	X		
Expedited Data Processing	X		
Packet Quality Monitoring	X		
Command interface w/ the EOC	X		
System Monitoring Interface	X		

Spacecraft Supported by the EPGS

Mission Profiles

Mission	Orbital Data Volume	Onboard Storage Capacity	Downlink Rates (bps)	Time Needed for X-Band Dump	Command Requirements (Freq., Duration)	Mission Period[1]
AM-1	110 Gbits	160 Gbits	150M (X-PB) 512K (S-PB) 16K (S-RT)	12.22 min/orbit	1 pass per day for loads; RT each pass for SSR dump control	NET 12/98 - 12/04
Landsat-7	Imaging: 878 Gbits/day 45MB/day H/K	378 GB	150M (X-PB/RT) 256K (S-PB) 1 or 4K (S-RT)	Use all 6 scheduled passes (6/day)	AGS DN passes for loads (2/day) RT each pass for PB	7/98 - 5/05
EO-1	80 Gbits/Day	40 Gbits	105M (X-PB) 1M (S-PB/RT) (lower LEO & B/U rates)	12.7 min/day	*1 pass per day for loads* *RT each pass for SSR dump control*	5/99 - 5/00
PM-1	47 Gbits	136 Gbits	150M (X-PB) 524K (S-PB) 16K (S-RT)	5.22 min/orbit	1 pass per day for loads RT each pass for SSR dump	12/00 - 12/06
ICESAT	2.97 Gbits	24 Gbits	40M (X-PB) 16K (S-RT) 256K (S-PB)	19.8 min/day	4-6 RT pass/day for SSR/DSU dump control 1 or 2 loads per day	7/01 - 7/06
CHEM-1	33 Gbits	88 Gbits	150M (X-PB) 524K (S-PB) 16K (S-RT)	3.67 min/orbit	1 pass per day for loads RT each pass for SSR dump control	12/02 - 12/08

Note 1: Mission durations assume 6 year lifetimes for AM, Landsat, PM, and CHEM spacecraft, and 5 year lifetimes for ICESAT space
Note 2: Numbers in parenthesis are the minimum number and duration of tracking passes (per day) needed to support mission accur
data was provided by EPGS.

Worst case EPGS loading year is 2004; AM-1, Landsat, PM-1, CHEM-1, ICESAT, and AM-2 all supported simultaneously (6 s

Operations Using Minimum TDRSS Support

Ground Station Scheduling

- EOS missions will have priority over other missions for scheduling EPGS resources. EOS Operations Center will provide scheduling system clear priority guidelines for EOS missions
- Simplified due to limited communication opportunities
- Conflicts easy to predict through orbit propagation
- RF interference during overlapping support is possible (under investigation)

Operations Considerations

- Due to limited communication coverage, anomaly resolution activities will b constrained
- Non-continuous coverage at the polar sites requires more robust spacecraft
- Use of TDRSS as a back-up for low rate communications without a TDRSS transponder
  - --Under consideration to provide spacecraft health and safety status during critical phases, e.g., launch and early orbit

Other Aspects of EPGS

Design of ground system elements interfacing with the ground stations has been simplified to accommodate interfaces at both TDRSS ground terminal and polar sites.

Automation is used to minimize operations staffing.

Operations planning must be based on constellation design and on timely transmission of high rate science data back to GSFC.

Summary

Utilizing EPGS reduces overall costs for the EOS Project

EDOS design and functions at the EPGS and WSC sites have been simplified and standardized to reduce operations costs.

EPGS will be fully equipped and operational by June 2000

EPGS design and communication coverage provide, on average, ample contact opportunities for all EPGS-supported spacecraft.

Future EOS spacecraft will continue using TDRSS in a back-up mode for command and control and in a primary mode for tracking and time correlation.

EDOS design and functions at the EPGS and WSC sites have been simplified and standardized to reduce operations costs.